

REDLINE VERSION



Hydraulic machines – Guidelines for dealing with hydro-abrasive erosion in kaplan, francis, and pelton turbines

Preview



THIS PUBLICATION IS COPYRIGHT PROTECTED

Copyright © 2019 IEC, Geneva, Switzerland

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing from either IEC or IEC's member National Committee in the country of the requester. If you have any questions about IEC copyright or have an enquiry about obtaining additional rights to this publication, please contact the address below or your local IEC member National Committee for further information.

IEC Central Office
3, rue de Varembe
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
info@iec.ch
www.iec.ch

About the IEC

The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

About IEC publications

The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigendum or an amendment might have been published.

IEC publications search - webstore.iec.ch/advsearchform

The advanced search enables to find IEC publications by a variety of criteria (reference number, text, technical committee,...). It also gives information on projects, replaced and withdrawn publications.

IEC Just Published - webstore.iec.ch/justpublished

Stay up to date on all new IEC publications. Just Published details all new publications released. Available online and once a month by email.

IEC Customer Service Centre - webstore.iec.ch/csc

If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: sales@iec.ch.

Electropedia - www.electropedia.org

The world's leading online dictionary on electrotechnology, containing more than 22 000 terminological entries in English and French, with equivalent terms in 16 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

IEC Glossary - std.iec.ch/glossary

67 000 electrotechnical terminology entries in English and French extracted from the Terms and Definitions clause of IEC publications issued since 2002. Some entries have been collected from earlier publications of IEC TC 37, 77, 86 and CISPR.

REDLINE VERSION



Hydraulic machines – Guidelines for dealing with hydro-abrasive erosion
in kaplan, francis, and pelton turbines

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

ICS 23.100.10; 27.140

ISBN 978-2-8322-6431-7

Warning! Make sure that you obtained this publication from an authorized distributor.

CONTENTS

FOREWORD.....	6
INTRODUCTION.....	8
1 Scope.....	9
2 Terms, definitions and symbols.....	9
3 Abrasion rate Prediction of hydro-abrasive erosion rate.....	13
3.1 Model for hydro-abrasive erosion depth.....	13
3.2 Reference model.....	15
3.2 Simplified hydro-abrasive erosion evaluation.....	15
4 Design.....	16
4.1 General.....	16
4.2 Selection of abrasion resistant materials with high resistance to hydro-abrasive erosion and coating.....	17
4.3 Stainless steel overlays.....	18
4.4 Water conveyance system.....	18
4.5 Valve.....	18
4.5.1 General.....	18
4.5.2 Protection (closing) of the gap between housing and trunnion.....	19
4.5.3 Stops located outside the valve.....	19
4.5.4 Proper capacity of inlet valve operator.....	19
4.5.5 Increase bypass size to allow higher guide vane leakage.....	20
4.5.6 Bypass system design.....	20
4.6 Turbine.....	20
4.6.1 General.....	20
4.6.2 Hydraulic design.....	20
4.6.3 Mechanical design.....	22
5 Operation and maintenance.....	29
5.1 Operation.....	29
5.2 Spares and regular inspections.....	30
5.3 Particle sampling and monitoring.....	30
6 Abrasion resistant materials Materials with high resistance to hydro-abrasive erosion.....	32
6.1 Guidelines concerning relative abrasion hydro-abrasive erosion resistance of materials including abrasion hydro-abrasive erosion resistant coatings.....	32
6.1.1 General.....	32
6.1.2 Discussion and conclusions.....	33
6.2 Guidelines concerning maintainability of abrasion hydro-abrasive erosion resistant coating materials.....	34
6.2.1 Definition of terms used in this subclause.....	34
6.2.2 Time between overhaul for protective coatings.....	34
6.2.3 Maintenance Repair of protective coatings.....	36
7 Guidelines on insertions into specifications.....	37
7.1 General.....	37
7.2 Properties of particles going through the turbine.....	38
7.3 Size distribution of particles.....	39
Mineral composition of particles for each of the above mentioned periods.....	
Annex A (informative) PL calculation example.....	41

Annex B (informative) Measuring and recording abrasion hydro-abrasive erosion damages.....	43
B.1 Recording abrasion hydro-abrasive erosion damage	43
B.2 Pelton runner without coating.....	44
B.3 Needle tip and mouth piece without coating	44
B.4 Pelton runner with hardcoating.....	44
B.5 Needle tip, seat ring and nozzle housing with coating	44
B.6 Francis runner and stationary labyrinth without coating.....	45
B.7 Francis runner with coating and stationary labyrinth.....	45
B.8 Guide vanes and facing plates without coating.....	46
B.9 Guide vanes and facing plates with coating.....	46
B.10 Stay vanes.....	46
B.11 Francis labyrinth seals uncoated.....	47
B.12 Kaplan uncoated.....	47
B.13 Kaplan coated.....	47
B.14 Sample data sheets.....	47
B.15 Inspection record, runner blade inlet.....	49
B.16 Inspection record, runner blade outlet.....	50
B.17 Inspection record, runner band	51
B.18 Inspection record, guide vanes.....	52
B.19 Inspection record, facing plates and covers	53
B.20 Inspection record, upper stationary seal.....	54
B.21 Inspection record, upper rotating seal.....	55
B.22 Inspection record, lower stationary seal.....	56
B.23 Inspection record, lower rotating seal.....	57
B.24 Inspection record, runner bucket.....	58
B.25 Inspection record, Pelton runner splitter.....	59
Annex C (informative) Monitoring of particle concentration and properties and water sampling procedure	60
C.1 General.....	60
C.2 Sampling before building a power station.....	60
C.3 Sampling in existing power stations	61
C.4 Logging of samples.....	61
Annex D (informative) Procedures for analysis of particle concentration, size, hardness and shape	62
D.1 General.....	62
D.2 Particle concentration	62
D.3 Particle size distribution.....	62
D.4 Mineralogical composition of the particles	62
D.5 Particle geometry.....	63
Annex E (informative) Tests of abrasion resistant materials	63
Annex E (informative) Frequency of sediment sampling.....	76
Annex F (informative) Typical criteria to determine overhaul time due to abrasion hydro-abrasive erosion	77
F.1 General.....	77
F.2 Parameters which are observable while the unit is in operation.....	77
F.3 Criteria that require internal inspection of the unit.....	78
Annex G (informative) Example to calculate the amount of erosion in the full model the hydro-abrasive erosion depth.....	79

Annex H (informative) Examples to calculate the TBO in the reference model.....	81
Annex I (informative) Background for hydro-abrasive erosion depth model	84
I.1 Theoretical model Model background and derivation.....	84
I.2 Introduction to the <i>PL</i> variable.....	85
I.3 Survey results Calibration of the formula.....	88
Annex J (informative) Quality control of thermal sprayed WC-CoCr.....	89
J.1 Specification	89
J.2 Quality control	89
Bibliography.....	90
<hr/>	
Figure – Development of spiral pressure over time	
Figure 1 – Estimation of the characteristic velocities in guide vanes, W_{gv} , and runner, W_{run} , as a function of turbine specific speed	13
Figure 2 – Simplified evaluation of risk of hydro-abrasive erosion for first assessment.....	15
Figure 3 – Example of protection of transition area	17
Figure 4 – Runner blade overhang in refurbishment project	19
Figure 5 – Example of "mouse ear" cavitation on runner band due to thicker blades	20
Figure 6 – Detailed Example of design of guide vane trunnion seals	21
Figure 7 – Example of fixing of facing plates from the dry side (bolt to the left)	23
Figure 8 – Head cover balancing pipes with bends.....	24
Figure 9 – Step labyrinth with optimized shape for hardcoating.....	26
Figure 10 – Sample plot of particle concentration versus time.....	29
Figure D.1 – Typical examples of particle geometry	58
Figure I.1 – Example of flow pattern in a Pelton injector at different load	71
<hr/>	
Table – Form for mineral composition of particles for each of the above mentioned periods	
Table 1 – Values of K_f and p for various components.....	13
Table 2 – Overview over the feasibility for repair C on site.....	32
Table 3 – Form for properties of particles going through the turbine.....	34
Table 4 – Form for size distribution of particles.....	35
Table A.1 – Example of documenting sample tests	36
Table A.2 – Example of documenting sample results	37
Table B.1 – Inspection record, runner blade inlet form	43
Table B.2 – Inspection record, runner blade outlet form	44
Table B.3 – Inspection record, runner band form.....	45
Table B.4 – Inspection record, guide vanes form.....	46
Table B.5 – Inspection record, facing plates and covers form.....	47
Table B.6 – Inspection record, upper stationary seal form.....	48
Table B.7 – Inspection record, upper rotating seal form	49
Table B.8 – Inspection record, lower stationary seal form	50
Table B.9 – Inspection record, lower rotating seal form.....	51
Table B.10 – Inspection record, runner bucket.....	52
Table B.11 – Inspection record, Pelton runner splitter.....	53

Table G.1 – Calculations.....	65
Table H.1 – Pelton turbine calculation example.....	66
Table H.2 – Francis turbine calculation example	67
Table I.1 – Data analysis of the supplied questionnaire Analysis of the calibration constant K_f and p	73
Table J.1 – Recommended items to include in HVOF inspection	74

Preview

Copyright

INTERNATIONAL ELECTROTECHNICAL COMMISSION

**HYDRAULIC MACHINES –
GUIDELINES FOR DEALING WITH HYDRO-ABRASIVE
EROSION IN KAPLAN, FRANCIS, AND PELTON TURBINES**

FOREWORD

- 1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
- 2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
- 3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
- 4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
- 5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
- 6) All users should ensure that they have the latest edition of this publication.
- 7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
- 8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
- 9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

DISCLAIMER

This Redline version is not an official Standard and is intended to provide the user with an indication of what changes have been made to the previous version. Only the IEC International Standard provided in this package is to be considered the official Standard.

This Redline version provides you with a quick and easy way to compare all the changes between this standard and its previous edition. A vertical bar appears in the margin wherever a change has been made. Additions are in green text, deletions are in strikethrough red text.

International Standard IEC 62364 has been prepared by IEC technical committee 4: Hydraulic turbines.

This second edition cancels and replaces the first edition published in 2013. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

- a) the formula for TBO in Pelton reference model has been modified;
- b) the formula for calculating sampling interval has been modified;
- c) the chapter in hydro-abrasive erosion resistant coatings has been substantially modified;
- d) the annex with test data for hydro-abrasive erosion resistant materials has been removed;
- e) a simplified hydro-abrasive erosion evaluation has been added.

The text of this International Standard is based on the following documents:

FDIS	Report on voting
4/351/FDIS	4/366/RVD

Full information on the voting for the approval of this International Standard can be found in the report on voting indicated in the above table.

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under "<http://webstore.iec.ch>" in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

INTRODUCTION

~~Many owners of hydroelectric plants contend with the sometimes very aggressive deterioration of their machines due to particle abrasion. Such owners must find the means to communicate to potential suppliers of machines for their sites, their desire to have the particular attention of the designers at the turbine design phase, directed to the minimization of the severity and effects of particle abrasion.~~

The number of hydro power plants with hydro-abrasive erosion is increasing worldwide.

An overall approach is needed to minimize the impact of this phenomenon. Already at the start of the planning phase an evaluation should be done to quantify the hydro-abrasive erosion and the impact on the operation. For this, the influencing parameters and their impact on the hydro-abrasive erosion have to be known. The necessary information for the evaluation comprises among others the future design, the particle parameters of the water, which will pass the turbine, the reservoir sedimentation and the power plant owner's framework for the future operation like availability or maximum allowable efficiency loss, before an overhaul needs to be done.

Based on this evaluation of the hydro-abrasive erosion, an optimised solution can then be found, by analysing all measures in relation to investments, energy production and maintenance costs as decision parameters. Often a more hydro-abrasive erosion-resistant design, instead of choosing the turbine design with the highest efficiency, will lead to higher revenue. This analysis is best performed by the overall plant designer.

With regards to the machines, owners should find the means to communicate to potential suppliers for their sites, their desire to have the particular attention of the designers at the turbine design phase, directed to the minimization of the severity and effects of hydro-abrasive erosion.

Limited consensus and very little quantitative data exists on the steps which the designer could and should take to extend the useful life before major overhaul of the turbine components when they are operated under severe ~~particle abrasion~~ hydro-abrasive erosion service. This has led some owners to write into their specifications, conditions which cannot be met with known methods and materials.

HYDRAULIC MACHINES – GUIDELINES FOR DEALING WITH HYDRO-ABRASIVE EROSION IN KAPLAN, FRANCIS, AND PELTON TURBINES

1 Scope

This document gives guidelines for:

- a) presenting data on ~~particle abrasion~~ hydro-abrasive erosion rates on several combinations of water quality, operating conditions, component materials, and component properties collected from a variety of hydro sites;
- b) developing guidelines for the methods of minimizing ~~particle abrasion~~ hydro-abrasive erosion by modifications to hydraulic design for clean water. These guidelines do not include details such as hydraulic profile shapes which ~~should be~~ are determined by the hydraulic design experts for a given site;
- c) developing guidelines based on “experience data” concerning the relative resistance of materials faced with ~~particle abrasion~~ hydro-abrasive erosion problems;
- d) developing guidelines concerning the maintainability of ~~abrasion-resistant~~ materials with high resistance to hydro-abrasive erosion and hard ~~facing~~ coatings;
- e) developing guidelines on a recommended approach, which owners could and should take to ensure that specifications communicate the need for particular attention to this aspect of hydraulic design at their sites without establishing criteria which cannot be satisfied because the means are beyond the control of the manufacturers;
- f) developing guidelines concerning operation mode of the hydro turbines in water with particle materials to increase the operation life.

It is assumed in this document that the water is not chemically aggressive. Since chemical aggressiveness is dependent upon so many possible chemical compositions, and the materials of the machine, it is beyond the scope of this document to address these issues.

It is assumed in this document that cavitation is not present in the turbine. Cavitation and ~~abrasion may~~ hydro-abrasive erosion can reinforce each other so that the resulting erosion is larger than the sum of cavitation erosion plus ~~abrasion~~ hydro-abrasive erosion. The quantitative relationship of the resulting ~~abrasion~~ hydro-abrasive erosion is not known and it is beyond the scope of this document to assess it, except to ~~recommend~~ suggest that special efforts be made in the turbine design phase to minimize cavitation.

Large solids (e.g. stones, wood, ice, metal objects, etc.) traveling with the water ~~may~~ can impact turbine components and produce damage. This damage ~~may~~ can in turn increase the flow turbulence thereby accelerating wear by both cavitation and ~~abrasion~~ hydro-abrasive erosion. ~~Abrasion~~ Hydro-abrasive erosion resistant coatings can also be damaged locally by impact of large solids. It is beyond the scope of this document to address these issues.

This document focuses mainly on hydroelectric powerplant equipment. Certain portions ~~may~~ can also be applicable to other hydraulic machines.

2 Terms, definitions and symbols

For the purposes of this document, the following terms and definitions ~~and symbols~~ apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at <http://www.electropedia.org/>
- ISO Online browsing platform: available at <http://www.iso.org/obp>

NOTE 1 Terms and definitions are also based, where relevant, on IEC TR 61364.

NOTE 2 The International System of Units (S.I.) is adopted throughout this document but other systems are allowed.

Sub-clause	Term	Definition	Symbol	Unit
2.2.1	specific hydraulic energy of a machine	specific energy of water available between the high and low pressure reference sections 1 and 2 of the machine Note 1 to entry: For full information, see IEC 60193.	E	J/kg
2.2.2	acceleration due to gravity	local value of gravitational acceleration at the place of testing Note 1 to entry: For full information, see IEC 60193.	g	m/s ²
2.2.3	turbine head pump head	available head at hydraulic machine terminal $H = E/g$	H	m
2.2.4	reference diameter	reference diameter of the hydraulic machine Note 1 to entry: For Pelton turbines this is the pitch diameter, for Kaplan turbines this is the runner chamber diameter and for Francis and Francis type pump turbines this is the blade low pressure section diameter at the band Note 2 to entry: See IEC 60193 for further information.	D	m
2.2.5	hub diameter	the diameter of runner hub for Kaplan turbines	D_h	mm
2.2.56	abrasion hydro-abrasive erosion depth	depth of metal layer that has been removed from a component due to particle abrasion material removed (measured perpendicular to the original surface) from a component due to hydro-abrasive erosion	S	mm
2.2.67	characteristic velocity	characteristic velocity defined for each machine component and used to quantify particle abrasion hydro-abrasive erosion damage Note 1 to entry: See also 2.2.20 to 2.2.24.	w	m/s
2.2.78	particle concentration	mass concentration of all solid particles per m ³ of water solution particles, i.e. the mass of solid particles per volume of water-particle mixture Note 1 to entry: In case the particle concentration is expressed in parts per million (ppm) it is recommended to use the mass of particles per mass volume of water, so that 1 000 ppm approximately corresponds to 1 kg/m ³ .	C	kg/m ³

Sub-clause	Term	Definition	Symbol	Unit
2.2.89	particle load	<p>the particle concentration integrated over the time, T, that is under consideration</p> <p>the integral of the modified particle concentration over time:</p> $PL = \int_0^T C(t) \times K_{\text{size}}(t) \times K_{\text{shape}}(t) \times K_{\text{hardness}}(t) dt$ $\left(\approx \sum_{n=1}^N C_n \times K_{\text{size},n} \times K_{\text{shape},n} \times K_{\text{hardness},n} \times T_{s,n} \right)$ <p>$C(t) = 0$ if no water is flowing through the turbine.</p> <p>If the unit is at standstill with pressurized spiral case then $C(t)=0$ when calculating PL for runner and labyrinth seals, but $C(t) \neq 0$ when calculating PL for guide vanes and facing plates.</p> <p>Note 1 to entry: For Francis turbines $C(t) = 0$ when calculating PL for runner and labyrinth seals, if the unit is at standstill with pressurized spiral case, but $C(t) \neq 0$ when calculating PL for guide vanes and facing plates.</p>	PL	$\text{kg} \times \text{h}/\text{m}^3$
2.2.910	size factor	factor that characterizes how the abrasion hydro-abrasive erosion relates to the size of the abrasive particles = median particle size dP_{50} in mm	K_{size}	
2.2.1011	shape factor	factor that characterizes how the abrasion hydro-abrasive erosion relates to the shape of the abrasive particles	K_{shape}	
2.2.1112	hardness factor	<p>factor that characterizes how the abrasion hydro-abrasive erosion relates to the hardness of the abrasive particles</p> <p>Note 1 to entry: See Annex D.</p> <p>for 13C44 stainless steel: K_{hardness} = fraction of particles harder than Mohs 4,5.</p> <p>for hard coated surfaces: K_{hardness} = fraction of particles harder than Mohs 7,0.</p>	K_{hardness}	
2.2.1213	material factor	factor that characterizes how the abrasion hydro-abrasive erosion relates to the material properties of the base material		
2.2.1314	flow coefficient	coefficient that characterizes how the abrasion hydro-abrasive erosion relates to the water flow around each component	K_f	$\frac{\text{mm} \times \text{s}^{3,4}}{\text{kg} \times \text{h} \times \text{m}^\alpha}$
2.2.1415	sampling interval	time interval between two water samples taken to determine the concentration of abrasive particles in the water	T_s	h
2.2.1516	yearly particle load	Total load (PL) for 1 year of operation, i.e. PL for $T = 8760$ h calculated in accordance with 2.2.89	PL_{year}	$\text{kg} \times \text{h}/\text{m}^3$
2.2.16	maximum concentration	the maximum concentration of abrasive particles over a specified time interval	C_{max}	kg/m^3
2.2.17	maximum particle load	<p>maximum value of the integrand in the PL integral during a specified time interval, i.e. the maximum value of the following expression</p> $PL_{\text{max}} = C(t) \times K_{\text{size}}(t) \times K_{\text{shape}}(t) \times K_{\text{hardness}}(t)$	PL_{max}	kg/m^3

Sub-clause	Term	Definition	Symbol	Unit
2.2.1718	particle median diameter	median diameter of abrasive particles in a sample, i.e. such diameter that the particles with size smaller than the value under consideration represent 50 % of the total mass of particles in the sample	dP_{50}	mm
2.2.18	wear resistance index	abrasion depth or volume of a reference material (generally some version stainless steel) divided by the abrasion depth or volume of the material in question, tested under the same conditions	WRI	-
2.2.19	impingement angle	angle between the particle trajectory and the surface of the substrate		°
2.2.20	characteristic velocity in Francis guide vanes characteristic velocity in Kaplan guide vanes	flow through unit divided by the minimum flow area at the guide vane apparatus estimated at best efficiency point $W_{gv} = \frac{Q}{a \times Z_0 \times B_0}$	W_{gv}	m/s
2.2.21	characteristic velocity in guide vanes of Kaplan, Francis or tubular turbines	speed of the water flow at guide vane location $W_{gv} = 0,5 \times \sqrt{2 \times E}$	W_{gv}	m/s
2.2.221	characteristic velocity in Pelton injector	speed of the water flow at injector location $W_{inj} = \sqrt{2 \times E}$	W_{inj}	m/s
2.2.2322	characteristic velocity in Kaplan or Francis tubular turbine runner	relative velocity between the water and the runner blade estimated with below formulas at best efficiency point $W_{run} = \sqrt{u_2^2 + c_2^2}$ $u_2 = n \times \pi \times D$ $c_2 = \frac{Q \times 4}{\pi \times D^2} \text{ (Francis)}$ $c_2 = \frac{Q \times 4}{\pi \times (D^2 - D_h^2)} \text{ (Kaplan)}$ Note 1 to entry: In calculation of c_2 for Kaplan turbines, the hub diameter has been neglected in the interest of simplicity.	W_{run}	m/s
2.2.2423	characteristic velocity in Pelton runner	speed of the water flow at a Pelton runner relative velocity between the water and the runner bucket $W_{run} = 0,5 \times \sqrt{2 \times E}$	W_{run}	m/s
2.2.2524	discharge (volume flow rate)	volume of water per unit time passing through any section in the system	Q	m ³ /s
2.2.2625	guide vane opening	average shortest distance between adjacent guide vanes (at a specified section if necessary) Note 1 to entry: For further information, see IEC 60193.	a	m
2.2.2726	number of guide vanes	total number of guide vanes in a turbine	z_0	

Sub-clause	Term	Definition	Symbol	Unit
2.2. 28 27	distributor height	height of the distributor in a turbine	B_0	m
2.2. 29 28	rotational speed	number of revolutions per unit time	n	1/s
2.2. 30 29	specific speed	commonly used specific speed to of a hydraulic machine $n_s = \frac{60 \times n \times \sqrt{P}}{H^{5/4}}$ <p>P and H are taken in the rated operating point and given in kW and m respectively</p>	n_s	rpm
2.2. 31 30	output	output of the turbine in the rated operating point	P	kW
2.2. 32 31	actual abrasion hydro-abrasive erosion depth of target unit	estimated actual depth of metal that will be removed from a component of the target turbine due to particle abrasion hydro-abrasive erosion Note 1 to entry: For use with the reference model.	$S_{\text{target, actual}}$	mm
2.2. 33 32	actual abrasion hydro-abrasive erosion depth of reference unit	the actual hydro-abrasive erosion depth of metal that has been removed from a component of the reference turbine due to particle abrasion hydro-abrasive erosion Note 1 to entry: For use with the reference model.	$S_{\text{ref, actual}}$	mm
2.2. 34 33	number of nozzles	number of nozzles in a Pelton turbine	z_0, z_{jet}	
2.2. 35 34	bucket width	bucket width in a Pelton runner	B_2	mm
2.2. 36 35	number of buckets	number of buckets in a Pelton runner	z_2	
2.2. 37 36	time between overhaul for target unit	time between overhaul for target unit Note 1 to entry: For use with the reference model.	TBO_{target}	h
2.2. 38 37	time between overhaul for reference unit	time between overhaul for reference unit Note 1 to entry: For use with the reference model.	TBO_{ref}	h
2.2. 39 38	turbine reference size	reference size for calculation curvature dependent effects of hydro-abrasive erosion Note 1 to entry: For Francis turbines, it is the reference diameter, D (see 2.2.4). Note 2 to entry: For Pelton turbines it is the inner bucket width, B_2 . Note 3 to entry: For further information in the inner bucket width, B_2 , see IEC 60609-2.	RS	m
2.2. 40 39	size exponent	exponent that describes the size dependant effects of hydro-abrasive erosion in evaluating RS	p	
2.2. 41 40	exponent	numerical value of $0,4-p$ that balances units for K_f	a	

3 ~~Abrasion rate~~ Prediction of hydro-abrasive erosion rate

3.1 Model for hydro-abrasive erosion depth

The following formula can be used to estimate the hydro-abrasive erosion depth in a Francis turbine:

ALTIJD DE ACTUELE NORM IN UW BEZIT HEBBEN?

Nooit meer zoeken in de systemen en uzelf de vraag stellen:
'Is IEC 62364:2019-RL en de laatste versie?'

Via het digitale platform NEN Connect heeft u altijd toegang tot de meest actuele versie van deze norm. Vervallen versies blijven ook beschikbaar. **U en uw collega's** kunnen de norm via NEN Connect makkelijk raadplagen, online en offline.

Kies voor slimmer werken en bekijk onze mogelijkheden op www.nenconnect.nl.

Heeft u vragen?

Onze Klantenservice is bereikbaar maandag tot en met vrijdag, van 8.30 tot 17.00 uur.

Telefoon: 015 2 690 391

E-mail: klantenservice@nen.nl

